An Econometric Analysis of US Airline Flight Delays with Time-of-Day Effects

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Outline

- Introduction
- Model
  - Factors
  - Data
- Estimation Results
- Delay Change Decomposition
- Conclusions
Introduction:
Arrival Delays & Scheduled Arrivals

![Graph showing arrival delays and scheduled arrivals over time.](https://via.placeholder.com/150)
Goals

- Develop statistical model to forecast delay in the NAS
- Certain advantages over simulation models
  - Estimated over large number of days
  - Reduced data needs
  - Instantaneous calculation
  - Future year prediction based on application to a full year of days rather than a few sample days
- Compare results with simulation
Objectives

- Model daily average arrival delay
- Assess impacts of
  - Queuing
  - Volume
  - Weather (storm and terminal conditions)
  - Seasonal Effects
- Investigate time of day effects for queuing delay
Model

\[ AvDelay(t) = f(\text{Queuing}(t), SFlights(t), GAFlights(t), MFlights(t), IFR(t), Windspeed(t), THX(t), Events(t), Season(t), Period(t)) + \nu_t \]
Queuing

- Calculate deterministic queuing delay on a daily basis for each of 32 DOT airports
- Based on
  - Quarter-hr demand profile (based on schedule and adjusted for cancelled flights)
  - Quarter-hr AAR
Queuing: Procedure

- **Airport level**
  - Construct Cumulative Arrival Demand Curve
  - Construct Cumulative Arrival Count Curve
  - Calculate Delay as Area Between Demand and Count Curves

- **System level**
  - Summed airport delays to get total delay
  - Divided by total arrivals to get average delay
En Route Weather (Storms)

- Based on Surface Summary of the Day from NOAA (National Oceanographic and Atmospheric Administration)
- Daily summary from ~1500 US weather stations
- Each station reports binary (yes/no) thunderstorm variable
- Used proportion reporting thunderstorms as storm metric
  - Construct area-specific thunderstorm metrics on lat-long quadrangles
  - Include each metric as separate explanatory variable
Terminal Weather

- Proportion of the day under IFR
  - Airport IFR proportion: proportion of time under IFR
  - System IFR proportion: weight airport IFR proportion by # of operations
  - Higher IFR proportion, expected higher delay due to lower AAR

- Wind speed
  - Airport wind speed: avg. wind speed of the day
  - System wind speed: weight airport wind speed by # of operations
  - Higher wind speed, expected higher delay
Other Effects

- Volume
  - Scheduled arrivals
  - GA operations
- Monthly fixed effects
  - Based on month
  - Effects of winds and other weather factors
- Yearly fixed effects
  - Year-to-year trends not otherwise accounted for
  - May reflect FAA performance among other factors
- UA strike effect
- 9/11 Effect
Estimation

Data

- Daily data: Jan. 2000- June 2005
- Excludes 12/20-25, 9/11-30/01, and standard/daylight savings transition days

Estimations

- OLS model: Heteroskedasticity and autocorrelation
- GARCH model
  
  Model form

  \[
  y_t = X_t' \beta + \nu_t \\
  \nu_t = \varepsilon_t - AR1 \cdot \nu_{t-1} \\
  \varepsilon_t = \sqrt{h_t} \cdot e_t \\
  h_t = ARCH 0 + ARCH1 \cdot \varepsilon^2_{t-1} + GARCH1 \cdot h_{t-1} + HET1 \cdot Q(t) \\
  e_t \sim IN(0,1)
  \]
## Estimation Results

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<td>Queuing</td>
<td>intercept</td>
<td>1.457</td>
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<td>1.448</td>
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<td>Queuing (00:00--08:00)</td>
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<td>0.895</td>
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<td>3.099</td>
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<td>Queuing (12:00--16:00)</td>
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<td>2.236</td>
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<td>Queuing (16:00--24:00)</td>
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<td>1.029</td>
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<td>Queuing²</td>
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<td>-0.074</td>
<td>0.024</td>
<td>-0.082</td>
<td>0.025</td>
<td>-0.072</td>
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<td>Volume</td>
<td>Scheduled arrivals (000)</td>
<td>0.964</td>
<td>0.157</td>
<td>1.009</td>
<td>0.153</td>
<td>0.771</td>
<td>0.163</td>
<td>0.675</td>
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<td>GA operations (000)</td>
<td>0.098</td>
<td>0.030</td>
<td>0.031</td>
<td>0.030</td>
<td>0.073</td>
<td>0.030</td>
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<td>Terminals</td>
<td>IFR ratio</td>
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<td>0.824</td>
<td>13.524</td>
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<td>Weather</td>
<td>Wind speed</td>
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<td>Sch*IFR ratio</td>
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<td>En Route</td>
<td>Storms in region 1</td>
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<td>0.658</td>
<td>1.684</td>
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<td>Storms in region 2</td>
<td>5.627</td>
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<td>Military Operations (000)</td>
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<td>Event</td>
<td>UA strike dummy</td>
<td>1.820</td>
<td>0.631</td>
<td>1.720</td>
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<td>2nd half 2001 after 9/11 dummy</td>
<td>0.042</td>
<td>0.883</td>
<td>0.281</td>
<td>0.875</td>
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<td>R-Squared</td>
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</table>

Note: "Scheduled arrivals" is abbreviated as "Sch."; Time dummies and GARCH variables are used but not shown here.
Key Findings

- Time of day queuing effects
  - Vary strongly by time-of-day
  - Greatest impact in morning (delay propagation)
  - Concave relationship

- Volume
  - Scheduled arrivals: 1000 additional scheduled flights increases average delay by 0.68-0.77 minutes on extremely good weather days
  - GA operations: 1000 additional GA operations in increases average delay by 0.1 minutes
  - Military operations: strong negative relationship with delay (!)
Key Findings (cont)

- Terminal weather effects
  - Depend on volume
  - Have impact even when controlling for queuing
- En route weather effects
  - Depend on volume
  - Wide geographic variation
- Other effects
  - 2000 UA job action had pronounced effect
  - Post 9/11 effect not significant (captured by other variables)
Conclusions

- Statistical models help us explain and predict delay changes
- Use of deterministic queuing increases fidelity of these models and allows time-of-day effects to be captured
- En route convective weather effects can be captured in fairly simple ways
- Substantial unexplained variation remains